Complete Summary

GUIDELINE TITLE

Recommendations for the standardization and interpretation of the electrocardiogram. Part I: the electrocardiogram and its technology. A scientific statement from the American Heart Association Electrocardiography and Arrhythmias Committee, Council on Clinical Cardiology; the American College of Cardiology Foundation; and the Heart Rhythm Society. Endorsed by the International Society for Computerized Electrocardiology.

BIBLIOGRAPHIC SOURCE(S)

Kligfield P, Gettes LS, Bailey JJ, Childers R, Deal BJ, Hancock EW, van Herpen G, Kors JA, Macfarlane P, Mirvis DM, Pahlm O, Rautaharju P, Wagner GS, American Heart Association Electrocardiography and Arrhythmias Committee, American College of Cardiology Foundation, Heart Rhythm Society, Josephson M, Mason JW, Okin P, Surawicz B, Wellens H. Recommendations for the standardization and interpretation of the electrocardiogram: part I: The electrocardiogram and its technology. Circulation 2007 Mar 13;115(10):1306-24. [164 references] PubMed

GUIDELINE STATUS

This is the current release of the guideline.

COMPLETE SUMMARY CONTENT

SCOPE

DISEASE/CONDITION(S)

Any disease/condition requiring the use of an electrocardiogram (ECG) including but not limited to:

- Acute coronary syndromes
- Intraventricular conduction disturbances and arrhythmias

- Electrolyte abnormalities, particularly of serum potassium and calcium
- Genetically mediated electrical or structural cardiac abnormalities
- Conditions treated with antiarrhythmic and other drugs

GUIDELINE CATEGORY

Diagnosis
Evaluation
Management
Prevention
Screening
Treatment

CLINICAL SPECIALTY

Cardiology
Family Practice
Internal Medicine

INTENDED USERS

Physicians

GUIDELINE OBJECTIVE(S)

- To examine the relation of the resting electrocardiogram (ECG) to its technology
- To foster understanding of how the modern ECG is derived and displayed
- To establish standards that will improve the accuracy and usefulness of the ECG in practice

TARGET POPULATION

Patients presenting with or at risk of, but not limited to:

- Acute coronary syndromes
- Intraventricular conduction disturbances and arrhythmias
- Electrolyte abnormalities, particularly of serum potassium and calcium
- Genetically mediated electrical or structural cardiac abnormalities
- Conditions treated with antiarrhythmic and other drugs

INTERVENTIONS AND PRACTICES CONSIDERED

Electrocardiogram (ECG)

MAJOR OUTCOMES CONSIDERED

Accuracy of electrocardiogram (ECG)

METHODOLOGY

METHODS USED TO COLLECT/SELECT EVIDENCE

Searches of Electronic Databases

DESCRIPTION OF METHODS USED TO COLLECT/SELECT THE EVIDENCE

Not stated

NUMBER OF SOURCE DOCUMENTS

Not stated

METHODS USED TO ASSESS THE QUALITY AND STRENGTH OF THE EVIDENCE

Expert Consensus

RATING SCHEME FOR THE STRENGTH OF THE EVIDENCE

Not applicable

METHODS USED TO ANALYZE THE EVIDENCE

Review

DESCRIPTION OF THE METHODS USED TO ANALYZE THE EVIDENCE

Not stated

METHODS USED TO FORMULATE THE RECOMMENDATIONS

Expert Consensus

DESCRIPTION OF METHODS USED TO FORMULATE THE RECOMMENDATIONS

The chairman (L.S.G.) was selected by the Electrocardiography and Arrhythmias Committee of the Council on Clinical Cardiology of the American Heart Association (AHA). He formed an advisory group to assist in setting goals and to recommend other writing group members. The committee met on 5 occasions to discuss goals, identify specific areas that required updating, and review progress. A smaller working/writing group with a group leader was chosen for each topic.

RATING SCHEME FOR THE STRENGTH OF THE RECOMMENDATIONS

Not applicable

COST ANALYSIS

A formal cost analysis was not performed and published cost analyses were not reviewed.

METHOD OF GUIDELINE VALIDATION

Internal Peer Review

DESCRIPTION OF METHOD OF GUIDELINE VALIDATION

This statement was approved by the American Heart Association Science Advisory and Coordinating Committee on October 26, 2006, by the American College of Cardiology Board of Trustees on October 12, 2006, and by the Heart Rhythm Society on September 6, 2006.

RECOMMENDATIONS

MAJOR RECOMMENDATIONS

The Electrocardiogram (ECG) Signal and Its Processing

Sampling the ECG Signal

Oversampling by a significant multiple of the upper-frequency cutoff is recommended to provide recommended bandwidth in the digitized signal. Manufacturers should continue to develop improved algorithms for the identification and quantitative presentation of pacemaker stimulus outputs and for their preservation during ECG storage and retrieval. Low-amplitude pacemaker stimulus outputs should not be artificially increased in amplitude to aid recognition, because this would distort the form of the recorded ECG. Instead, it is recommended that manufacturers incorporate a separate representation of detected pacemaker stimulus outputs into 1 row only of the standard output tracing that would aid the identification of atrial, ventricular, and biventricular pacing signals. The selected row might be a rhythm strip that accompanies the standard 3 rows of lead signals in 4 columns, or in the absence of a rhythm row, 1 of the standard rows might be selected for this purpose.

Low-Frequency Filtering

To reduce artifactual distortion of the ST segment, the 1990 American Heart Association (AHA) document recommended that the low-frequency cutoff be 0.05 hertz (Hz) for routine filters but that this requirement could be relaxed to 0.67 Hz or below for linear digital filters with zero phase distortion. The American National Standards Institute/Association for the Advancement of Medical Instrumentation (ANSI/AAMI) recommendations of 1991, affirmed in 2001, endorsed these relaxed limits for low-frequency cutoff for standard 12-lead ECGs, subject to maximum allowable errors for individual determinants of overall input signal reproduction. These standards continue to be recommended.

High-Frequency Filtering

The ANSI/AAMI standard of 1991, reaffirmed in 2001, recommended a high-frequency cutoff of at least 150 Hz for all standard 12-lead ECGs. The ANSI/AAMI document also details maximum allowable errors for individual determinants of overall input signal reproduction, which extend beyond the scope of the present report but are important guidelines for manufacturers. These most recent limits continue to be recommended for adolescents and for adults, with extension of the high-frequency cutoff to 250 Hz in children, subject to demonstration of fidelity testing by individual manufacturers according to standard methods. Electrocardiographs should automatically alert the user when a suboptimal high-frequency cutoff, such as 40 Hz, is used, and a proper high-frequency cutoff should automatically be restored between routine standard ECG recordings.

Formation of a Representative Single-Lead Complex

Digital electrocardiographs must provide beat alignment that allows selective averaging or formation of a representative complex with fidelity adequate for diagnostic ECG computer programs. Fidelity standards for construction of representative complexes need to be developed.

Global Measurement From Simultaneously Acquired Leads

Global measurements of intervals should be obtained from time-coherent data in multiple leads to detect the earliest onset and latest offset of waveforms. For routine purposes, global measurements of P-wave duration, PR interval, QRS duration, and QT duration should be stated on the ECG report. A comparative study is needed of global measurements made by different methods from a reference standard. Differences in global measurement algorithms and methods should be minimized to promote standardization, but these differences must be accounted for in comparative studies within individuals and between individuals. Attention must be paid to definition of normal ECG ranges in children and adolescents, as well as in adults, with stratification for specific age groups, sex, and race. Where methods vary, algorithm-specific normal ranges for intervals need to be derived. With respect to QT interval, the end of the T wave as determined globally should match with a well-defined T-wave offset in at least 1 of its component individual leads. Alternative methods of QT measurement from single or multiple leads may be prescribed for special purposes such as drug evaluation, but it is inappropriate for studies involving serial comparison of the QT interval to use differing methods of QT measurement within trials.

Data Compression for Transmission, Storage, and Retrieval of ECGs

Compression algorithms should perform in a manner that allows retrieved data to adhere to the fidelity standards established in the 1990 AHA statement with reference to the original signal.

Standard Leads

Location of Standard Limb and Precordial Electrodes

Technicians and other medical personnel responsible for the recording of ECGs should have periodic retraining in skin preparation, proper electrode positioning, and proper patient positioning. All leads are effectively "bipolar," and the differentiation between "bipolar" and "unipolar" in the description of the standard limb leads, the augmented limb leads, and the precordial leads is discouraged. Neither term should be used. Studies to clarify the effect of distal versus proximal limb lead electrode placement on ECG magnitudes and durations are required. Validity of test performance criteria for current diagnostic algorithms may be dependent on placement of limb leads in the same positions that were used for criteria development. Pending resolution of this issue, all ongoing studies used for criteria development must clearly document electrode placement with precision. The horizontal plane through V_4 is preferable to the fifth intercostals interspace for the placement of V_5 and V_6 and should be used for placement of these electrodes. Definition of V_5 as midway between V_4 and V_6 is conducive to greater reproducibility than occurs for the anterior axillary line, and this should be used when the anterior axillary line is not well defined. In the placement of V_6, attention should be directed to the definition of the midaxillary line as extending along the middle, or central plane, of the thorax. For the time being, it is recommended that electrodes continue to be placed under the breast in women until additional studies using electrodes placed on top of the breast are available.

Derivation of the Standard Limb Leads and Relationships Among Leads

Users should recognize the redundancy of information in the standard limb leads. Redundancy notwithstanding, the information contained in different perspectives from multiple leads can be used to improve recognition of ECG abnormalities.

Derivation of the Augmented Limb Leads and the Precordial Leads

The augmented limb leads of the frontal plane and the precordial leads result from derived electrode pairs and should not be described as "unipolar." Users should recognize the derived and redundant nature of the 3 augmented limb leads, but these are retained because multiple leads facilitate the clinical interpretation of the ECG.

Simultaneous Lead Presentation

Standard tracings obtained with digital electrocardiographs should provide accurate temporal alignment of multiple leads, with maximum misalignment of no more than 10 ms, and ideally as little as is practically feasible. The printed tracing may present temporally aligned groups of leads in different formats according to preference.

Alternative Information Format From Standard Leads

Routine use of the Cabrera sequence for display of the limb leads can be highly recommended as an alternative presentation standard. For display in a format of 4 columns of 3 leads, a left-to-right sequence (aVL to III) is logical because it is closer to traditional placement of limb lead I at the upper left. To maintain consistency, the left-to-right sequence is also recommended for horizontal display of the limb leads. However, it is recognized that the current limb lead array is so deeply entrenched in ECG tradition that change might take years to become

generally accepted. At present, manufacturers should be encouraged to make this display available as a routine option in new electrocardiographs.

Alternative Lead Application

Torso and Other Modified Placement of the Limb Leads

ECGs recorded with torso placement of the extremity electrodes cannot be considered equivalent to standard ECGs for all purposes and should not be used interchangeably with standard ECGs for serial comparison. Evaluation of the effect of torso placement of limb leads on waveform amplitudes and durations in infants is required. Tracings that use torso limb lead placement must be clearly labeled as such, including 12-lead tracings derived from torso limb lead placement in neonates or in young children and during ambulatory and exercise electrocardiography in adults. Furthermore, tracings recorded in the sitting or upright position should not be considered equivalent to standard supine ECGs.

Reduced Lead Sets

Synthesized 12-lead ECGs are not equivalent to standard 12-lead ECGs and cannot be recommended as a substitute for routine use. All 12-lead tracings derived by synthesis from reduced lead sets must be clearly labeled as such. Although synthesized ECGs that use the EASI lead system may be demonstrably adequate for some purposes, such as monitoring of rhythm, they cannot be considered equivalent to standard 12-lead recordings or recommended at present as an alternative for routine use.

Expanded Lead Sets

Because treatment of infarction may vary with right ventricular involvement, recording of additional right-sided precordial leads during acute inferior-wall left ventricular infarction is recommended. Routine recording of these leads in the absence of acute inferior infarction is not recommended. The use of additional posterior precordial leads can be recommended in settings in which treatment will depend on documentation of ST elevation during infarction or other acute coronary syndrome. Routine recording of these additional leads in the absence of an acute coronary syndrome is not recommended. As ST-segment vectors become increasingly used for improved diagnostic classification of myocardial infarction, the addition of a frontal plane ST-segment axis to the currently measured P-wave, QRS, and T-wave axes in the ECG header data is recommended.

Lead Switches and Misplacements

Limb Lead and Precordial Lead Switches

Medical personnel responsible for the recording of routine ECGs should receive training on the avoidance of lead switches and guidelines for their recognition. Lead-switch detection algorithms should be incorporated into digital electrocardiographs along with alarms for abnormally high lead impedance, and suspected misplacements should be identified to the person recording the ECG in time to correct the problem. If not corrected before recording, a diagnostic

statement alerting the reader to the presence of different types of lead switches should be incorporated into preliminary interpretive reports.

Lead Misplacement

Periodic retraining in proper lead positioning of the precordial leads should be routine for all personnel who are responsible for the recording of ECGs. Serial tracings in acute or subacute care settings should make use of some form of skin marking to promote reproducibility of lead placement when it is not possible to leave properly applied electrodes in place.

Computerized Interpretation of the ECG

Computer-based interpretation of the ECG is an adjunct to the electrocardiographer, and all computer-based reports require physician overreading. Accurate individual templates should be formed in each lead before final feature extraction and measurement used for diagnostic interpretation. Time-coherent data from multiple leads should be used to detect the earliest onset and latest offset of waveforms of global measurements used for diagnostic interpretation. Deterministic and statistical or probabilistic algorithms should be based on well-constructed databases that include varying degrees of pathology and an appropriate distribution of confounding conditions. Such algorithms should be validated with data that have not been used for development. Programs using complex diagnostic algorithms should document in reference material those measurements that are critical to the diagnostic statement, which might include synthesized vector loop or other novel measurements. Serial comparisons of sequential ECGs should be done by trained observers regardless of whether the ECG program provides a serial comparison. Assessment of the performance of different algorithms will be facilitated by use of a standardized glossary of interpretive statements.

CLINICAL ALGORITHM(S)

None provided

EVIDENCE SUPPORTING THE RECOMMENDATIONS

TYPE OF EVIDENCE SUPPORTING THE RECOMMENDATIONS

The type of evidence supporting the recommendations is not specifically stated for each recommendation.

BENEFITS/HARMS OF IMPLEMENTING THE GUIDELINE RECOMMENDATIONS

POTENTIAL BENEFITS

Appropriate use of the electrocardiogram (ECG) in order to improve ECG recording and interpretation

POTENTIAL HARMS

- A consequence of high-frequency recommendations is that reduction of noise by setting the high-frequency cutoff of a standard or monitoring electrocardiogram (ECG) to 40 hertz (Hz) will invalidate any amplitude measurements used for diagnostic classification.
- Tracings with Mason-Likar and other alternative lead placement may affect QRS morphology more than repolarization compared with the standard ECG; these differences can include false-negative and false-positive infarction criteria.
- Limb lead switches can result in false-positive and false-negative signs of ischemia.

IMPLEMENTATION OF THE GUIDELINE

DESCRIPTION OF IMPLEMENTATION STRATEGY

An implementation strategy was not provided.

INSTITUTE OF MEDICINE (IOM) NATIONAL HEALTHCARE QUALITY REPORT CATEGORIES

IOM CARE NEED

Getting Better
Living with Illness
Staying Healthy

IOM DOMAIN

Effectiveness

IDENTIFYING INFORMATION AND AVAILABILITY

BIBLIOGRAPHIC SOURCE(S)

Kligfield P, Gettes LS, Bailey JJ, Childers R, Deal BJ, Hancock EW, van Herpen G, Kors JA, Macfarlane P, Mirvis DM, Pahlm O, Rautaharju P, Wagner GS, American Heart Association Electrocardiography and Arrhythmias Committee, American College of Cardiology Foundation, Heart Rhythm Society, Josephson M, Mason JW, Okin P, Surawicz B, Wellens H. Recommendations for the standardization and interpretation of the electrocardiogram: part I: The electrocardiogram and its technology. Circulation 2007 Mar 13;115(10):1306-24. [164 references] PubMed

ADAPTATION

Not applicable: The guideline was not adapted from another source.

DATE RELEASED

2007 Mar 13

GUIDELINE DEVELOPER(S)

American College of Cardiology Foundation - Medical Specialty Society
American Heart Association - Professional Association
Heart Rhythm Society - Professional Association

SOURCE(S) OF FUNDING

American Heart Association

GUIDELINE COMMITTEE

Standardization and Interpretation of the Electrocardiogram Writing Group

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FINANCIAL DISCLOSURES/CONFLICTS OF INTEREST

The American Heart Association, the American College of Cardiology, and the Heart Rhythm Society make every effort to avoid any actual or potential conflicts of interest that may arise as a result of an outside relationship or a personal, professional, or business interest of a member of the writing panel. Specifically, all members of the writing group are required to complete and submit a Disclosure Questionnaire showing all such relationships that might be perceived as real or potential conflicts of interest.

Writing Group Disclosures

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James J. Bailey	National Institutes of	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honoraria	Ownership Interest	Consultant/Advi Board
	Health					
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Pentti Rautaharju	Wake Forest University Medical School–retired	None	None	None	None	Philips Medica Systems†
Gerard van Herpen	Erasmus Medical Center	None	None	None	None	None
Galen S. Wagner	Duke University Medical Center	Medtronic,† Physiocontrol,† Welch Allyn†	None	None	None	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (1) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (2) the person owns 5% or more of the voting stock or share of the

entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest

†Significant

Reviewer Disclosures

Reviewer	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honoraria	Ownership Interest	Consultant/A Board
Jonathan Abrams	University of New Mexico	None	None	None	None	None
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Peter Kowey	Lankenau Hospital and Main Line Health	None	None	Medifacts	Cardionet	Medifact
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This table represents the relationships of reviewers that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all reviewers are required to complete and submit.

ENDORSER(S)

International Society for Computerized Electrocardiology - Professional Association

GUIDELINE STATUS

This is the current release of the guideline.

GUIDELINE AVAILABILITY

Electronic copies: Available in Portable Document Format (PDF) from the American College of Cardiology (ACC) Web site, the Heart Rhythm Society Web site, and from the American Heart Association (AHA) Web site.

Print copies: Available from the American Heart Association, Public Information, 7272 Greenville Ave, Dallas, TX 75231-4596; Phone: 800-242-8721

AVAILABILITY OF COMPANION DOCUMENTS

None available

PATIENT RESOURCES

None available

NGC STATUS

This summary was completed by ECRI Institute on July 27, 2007. The information was verified by the guideline developer on August 24, 2007.

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